SPILL SERVO CONTROL BY DSP

H.Nakagawa, J.Kishiro, H.Sato, M.Shirakata, K.Marutsuka
High Energy Accelerator Research Organization, KEK

H.Tanaka, K.Onoue, K.Mochiki, S.Arai
Musashi Institute of Technology

Abstract

A feasibility study of the Digital Signal Processor (DSP) is now under going at KEK 12GeV proton synchrotron(PS). The DSP is expected as a new stand alone processor in the accelerator control because of its remarkable progress in the processing speed and outstanding forms of technology. Some applications of the DSP in the accelerator control system were already reported in ICALEPCS'97. We try to use the DSP in a beam feedback system and examine its reliability and flexibility in the accelerator control.

1 INTRODUCTION

KEK 12GeV PS slow beam extraction is carried out by employing the half resonance extraction[1]. This extraction scheme is sensitive to the fluctuation of the quadrupole, sextupole magnet and even in the transverse distribution of the beam. The stability requirement in the extracted beam is achieved by taking the beam feedback system, in which the short time fluctuation in the extracted beam intensity is fed back to the excitation current control of the extraction magnet. We investigated the transfer function between the extraction magnet and extracted beam intensity, and realized it by using an analogue circuit (spill servo system). The transfer function, however, to stabilize the extracted beam intensity shows more fine structure and dynamic variation than that enabled by a circuit. The function sometimes strongly depends on the circulating beam intensity, on the ripple of the main magnet and sometimes on the beam spectrum and so on[2]. Therefore, we try to use the DSP for the beam extraction feedback system, because it is too easy to adjust the transfer function by changing the software itself or the parameter implemented in the software.

2 DSP SYSTEM

2.1 Hardware

The frequency requirement in the spill servo system is ranging around 10kHz. The available DSP has the sampling rate around 700k samples/s, so that it is enough to match to the system requirement. Motorola DSP chip PC56301 is used for this system. At first, we examine the Motorola's development kit on a test stand in order to have an experience in the software design. Almost parallel to that, we developed a DSP board incorporating input AD converter and output DA converter. And at last, we are planning to make A/D + DSP + D/A circuit on 6U size VME board.

Figure 1 shows the development kit and our homemade test board (HTB-1).

(a) Development kit

(b) HTB-1

Figure 1: Two test boards.

The HTB-1 has large amount of memory for logging the feedback test condition and it transfers the data to VME host computer for analyzing the feedback condition.

2.2 Software

Slow extraction is done by cooperation of 5 septum magnets, 4 bump magnets, an octupole magnet, an extraction Q magnet (EQ) and 2 ripple Q magnets (RQ)[3].
Except EQ and RQ, the excitation pattern of the magnets is ordinary controlled by VME computer[4]. EQ and RQs are equipped for stabilize the extracted beam spill, and those are used for different frequency range. The EQ is operated from DC to 100 Hz. The RQ-1 is operated from 100 Hz to 1kHz, while the RQ-2 is from 1kHz to 10kHz. First test of EQ is made with integrator type program, same as realized by the analog circuit. Some feedback programs about RQ-1 were put to the test with beam.

3 TEST AND RESULTS

Figure 2 shows the test circuit. The beam intensity and spill signal are amplified and adjust its amplitude before put into the ADC.

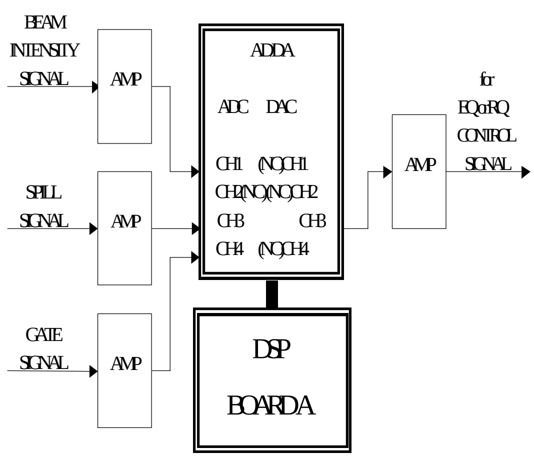

Figure 2: The test circuit of digital feedback

3.1 EQ feedback

EQ is installed for the adjustment of the betatron tune approaching to the half integer resonance. Then, at the beginning stage of EQ excitation, circulating beam is not extracted, which means that the extraction beam intensity monitor has no output signal. When some particles in the beam close to the half resonance and these will extracted, the beam monitor begins to out the signal. This stringent deference of the input signal condition into the feedback loop indicates that the loop characteristics must be different and it should be designed so as to implement the two feedback functions. And also transient of the functions need to be carefully investigated. Figure 3 shows an example of the EQ feedback.

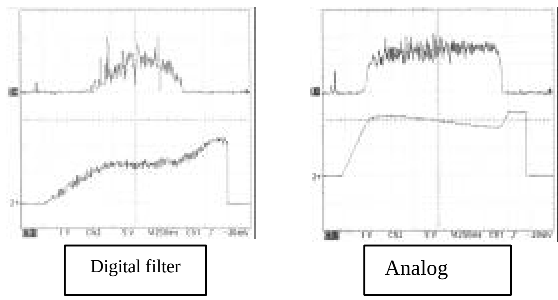

Figure 3: EQ feedback test

3.2 RQ feedback

For the RQ feedback experiment, the other software program was developed to implement the high-pass and band-pass filters. And the feedback component is mainly concentrated up to 100Hz, because RQs are prepared for this band. Spill signal was digitized by employing WE7000 waveform digitizer in order to analyze the structure in frequency region. In this experiment, digital feedback by DSP could reduce the fluctuation of spill. Detailed analysis in frequency region was done at three timing in a single extraction period. The results of Fourier analysis are shown in fig.4 (a), (b), (c).

We can find the fact that the spill structure has two types of components. First, a kind of broadband noise structure decreases with time. Second, the sharp spectrums are observed in all time. The later corresponds exactly to the harmonic frequency of the power line. It suggests that we must carefully avoid the induced noise in the signal line.

4 OBJECTIVES

The feedback system has 4 channels of A/D converter, 3 channels are already occupied for spill, intensity and gate signals. The other channel can be used for check the output voltage of power supply. So, at the feedback operation, saturation of power supply for EQ can use to make the reference value. Such operation by digital feedback can do easier than one by analog feedback. At next experiment, We wish to try non-linear feedback including the effect of saturation of power supply. Analysis shows that the structure of beam spill has some components that fluctuate with time. We wish to try time-dependent parameters method, namely, the feedback parameters will be changed with time. One of the important factors of digital feedback is time spending for calculation. The program used in our test was redundant, so that the cycle time was about 7μs. Our goal of cycle time is about 10μs, which includes calculation time of current references of 3 magnets. By considering the phase delay, this cycle time maintains the flat bandwidth of 10kHz, which is enough higher than required by our measurement.

5 CONCLUSION

This experiment shows the possibility to reduce the fluctuation of beam spill. The digital servo has really a potentiality to dynamically change the feedback system performance with time. And we expect the digital servo system, now developing, provides the new regime of the accelerator beam feedback system.

REFERENCES

[1] K. Endo, Y. Kimura *et. al.*, "Half integer resonance extraction from KEK-PS", Proc. Of the 2nd Symp. On Acc. Sci. & Tech, 157(1978).

[2] H. Sato, T. Toyama *et. al.*, "Analysis of the Servo-Spill control for slow beam extraction", Proc. Of the 9th Symp. On Acc. Sci. & Tech, Tsukuba, 25(1993).

[3] Y. Shoji, K. Marutsuka *et. al.*, "Slow extraction system of the KEK-PS", KEK Report, 93(1993).

[4] H.Nakagawa et.al., A Program Development Tool for KEK VME-MAP Control System, Proc. ICALEPCS'91 at KEK, KEK Proceedings 92-15(1992) p.322.

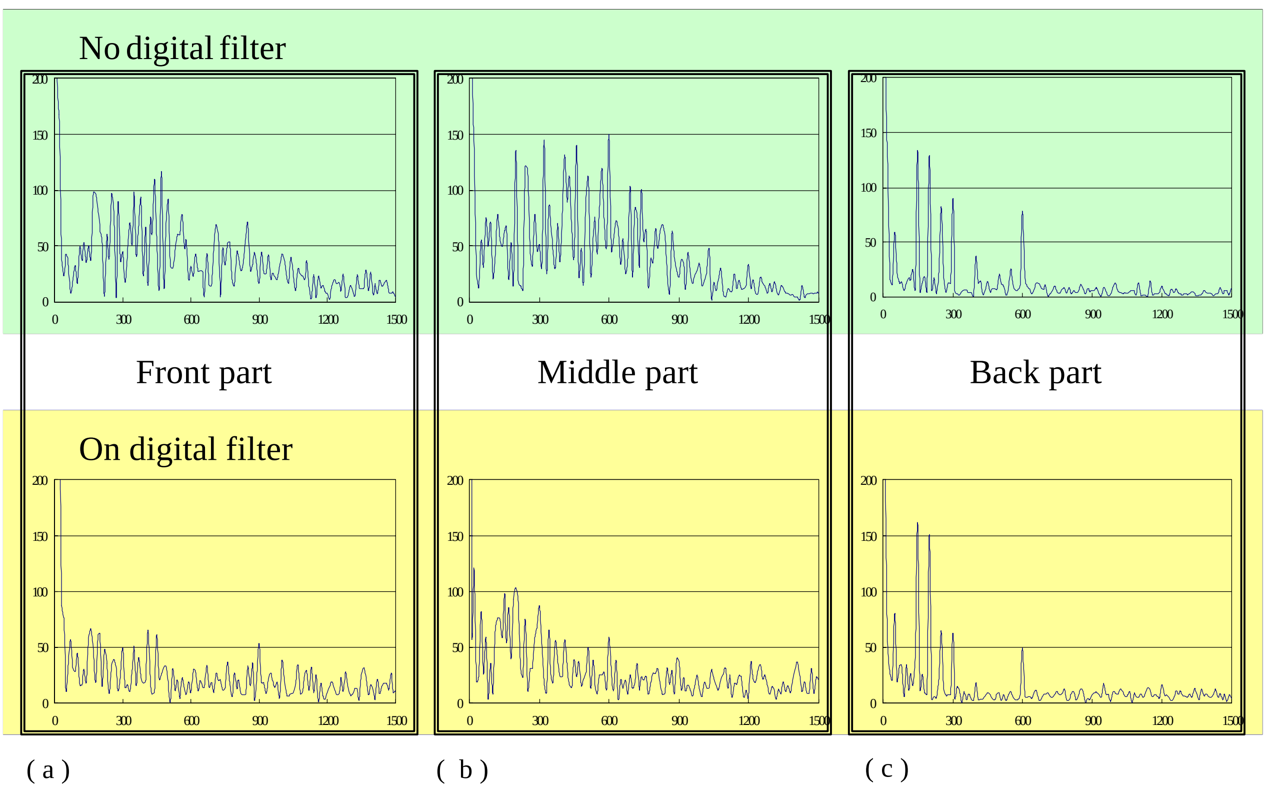

Fig. 4 Fourier analysis upper : without digital feedback of RQ
lower : with digital feedback of RQ